APPENDIX A

TABLE A
RETENTION TIME AND LOADING RATES ON WETLAND

Year	Annual Trucked Sewage Volume (m^3)	Hydraulic Retention Time in Pond 1[1] (days)	Wetland Loading Rates	
			Hydraulic[2] $m^3/ha/d$	Organic[3] kg $BOD_5/ha/d$
1994	10,900	22 to 47	21.1	7.9
1995	11,800	21 to 45	21.9	8.5
2000	14,800	18 to 40	24.6	10.7
2005	16,800	17 to 37	26.5	12.2
2010	19,300	16 to 34	28.7	14.0
2015	22,000	15 to 32	31.1	15.9

1. Hydraulic retention times:

Calculated based on pond volume of 1380 m^3 and 3000 m^3; and runoff and precipitation into P1 of 12 450 m^3 annually

2. Hydraulic loading rate:

$$\frac{(10\,900\ m^3/yr. + 12\,450\ m^3/yr.)}{16.5\ ha} \div 67\ days = 21.1\ m^3/ha/d$$

3. Organic loading rate:

$$\frac{(10\,900\ m^3/yr. \times 800\ BOD_5\ mg/L \times 1000L/m^3 \times 1\ kg/10^6 mg)}{16.5\ ha} \div 67\ days = 7.9\ kg\ BOD_5/ha/d$$

Treatment Processes

The treatment of the Chesterfield Inlet Wastewater Treatment System is highly effective, achieving greater than 90 percent removal of all regulated parameters. Discharge effluent to Finger Bay is well within criteria, both GNWT Water Board and CCME.

The processes to achieve this treatment include physical and biological. Physical operations at work including screening, sedimentation, and filtration. The slow moving water and plant life in the wetland enhance sedimentation of both organic and inorganic parameters. Some screening and filtration is also present due to the vegetation present.

Biological treatment is used primarily to removal biodegradable organic substrate, both dissolved and colloidal. Nutrient removal through conversion of ammonia to nitrate, followed by vegetative removal also is present. Phosphorous removal through vegetative uptake also appears to be present.

There are five basic functions of wetlands that make them attractive as wastewater treatment systems.

1. Dispersion of surface waters over a large area through intricate channelization of flow.

2. Physical entrapment of pollutants through sorption in the surface soils and organic litter.

3. Uptake and metabolic utilization by plants.

4. Utilization and transformation of elements by microorganisms.

5. Low energy and low maintenance requirements to attain consistent treatment levels (Doku and Heinke, 1993).

These functions are largely being met at the Chesterfield Inlet wetlands treatment system. Upon discharge from the primary treatment cell P1, the effluent flows over a large area, through the blockfield, including temporary storage in intermittent ponds and depression areas (Plates 2 and 3). Any additional release in the spring from the slow melting of the ice pile appears to be largely held within these depressional ponding areas.

Physical entrapment is evident in the areas of P1, P2, and P3, where black organic soils have developed. The sedges and aquatic vegetation have filtered organic debris and enhanced sedimentation of organic and mineral solids. Enhanced vegetative growth between P1, P2, and P3 is evidence of plant nutrient uptake (Plate 1). The lushness and diversity of the vegetation in the upper reaches of the study area contrasts sharply with the known nutrient deficiency of natural northern wetlands. Microbial activity is evident by the removal of greater than 90 percent of BOD_5 from the wastewater discharging from ponds P2 and P3.

The Design and Operations Concept Report (Dillon, 1994) identified the recommended option as one of monitoring with engineered upgrades of a "fail" condition was encountered. This first year of monitoring can be considered a "pass" condition. Two additional years of monthly monitoring during the frost-free period is recommended as identified in the Design and Operations Concept Report.

The significance of the vegetation present is not currently fully understood. The vegetation growth, adaptation, and stress will require further monitoring to allow greater confidence in predicting the level of area adaption or stress. Two soil samples taken at S1 and S4A indicate a soils pH of 6.9 to 7.2. The neutral soils, with organic contents of 50 to 70 percent are indicative of a non-stressed well operating system.

The calculated hydraulic loading rate during the frost-free days is 21.1 m^3/ha/d with current flows and 31.1 m^3/ha/d for design flows. Both loading rates are well below the 100 to 200 m^3/ha/d suggested as a design parameter by Doku and Heinke, 1993. The calculated design organic loading rate during frost-free days is 15.9 kg BOD_5/ha/d well above the maximum recommended 8 kg/ha/d. The current organic loading rate is estimated to be 7.9 kg BOD_5/ha/day. A range of wetland loading rates have been tabulated and included in Appendix A.

"The organic loading is used only as a check to ensure that sufficient oxygen will be present in the system to maintain aerobic conditions" (Doku & Heinke, 1993). The Chesterfield Inlet wetland system, however is made up of a blockfield, and many small ponds and depression areas. These physical features assist in entraining air into the effluent stream and also increasing the exposed water surface area. The significance of the exceedance of the recommended organic loading cannot be determined at this time. Additional effluent monitoring and more detailed examination of vegetation in subsequent years may determine if the wetlands system is stressed, or is operating within the treatment capacity as afforded by the wetland area which after about 10 years of operation appears to have adapted to the present organic load being imposed on it.

4.0 CONCLUSIONS AND RECOMMENDATIONS

- The wetlands treatment system at Chesterfield Inlet is defined as the area extending from the truck sewage discharge point to the wastewater effluent discharge location at Finger Bay confined by the north, south, and east by bedrock ridges. The wetlands area is made up of a series of ponds, rock boulders, and abundant and diverse vegetation.

- The wetlands treatment system is highly effective in removing organic solids, nutrients, and coliform loadings achieving greater than 90 percent removals prior to discharge to Finger Bay.

- The discharge concentrations do not appear to be seasonally dependent possibly due to increased precipitation in early summer causing dilution, hydraulic surge retention/equalization by overland flow expansion (to P_3), and increased treatment in summer and fall resulting in increased removals.

- The current hydraulic loading rate during the frost-free days is 21.1 m^3/ha/d well below the 100 to 200 m^3/ha/d suggested as design criteria for natural wetlands by Doku and Heinke, 1993.

- The current organic loading rate during frost-free days is 7.9 kg/ha/d within the maximum recommended, 8 kg/ha/d; identified to maintain aerobic conditions (Doku & Heinke, 1993). Aerobic conditions are maintained through the natural effluent flow through boulder fields, small ponds, and depression areas.

- Soils analysis at two locations identified an organic content of 50 to 70 percent and a neutral pH. The soils pH is an indication that the system is functioning well.

- As recommended in the Design and Operations Concept Report (Dillon, 1994), effluent and vegetative monitoring should be continued for two more years to better assess impact effects of the sewage on the wetland area. This monitoring could provide a basis for developing design criteria for future wetland site construction using less conservative loading factors than are currently published.

- The current Water Board surveillance point identified to meet licence requirements is "directly below sewage disposal area." The entire defined wetlands area is used as the wastewater treatment system and should be recognized as such in the license. It is also recommended the surveillance point for license compliance be identified as being located northwest of Pond 4 near the discharge to Finger Bay. This represents the outfall from the wetland treatment system.

TABLE 3: SECONDARY TREATMENT

Analyte	Average Concentration	Concentration Range	Average Removal
BOD_5 (mg/L)	6	<5 to 18	99%
TSS (mg/L)	16	<5 to 77	97%
Ammonia (mg/L)	2.2	<0.02 to 18.6	98%
Phosphorous (mg/L)	0.34	0.008 to 0.851	99%
Fecal Coliform (CFU/100 ml)	262	0 to 2300	>99%
Wastewater effluent exiting P2 and P3 (Columns C, D, F, G, H - Table 1)			

Tertiary Treatment

Tertiary treatment occurs in the area between ponds P2 and P3 to the shore of Finger Bay. Additional removal of nutrients is low as evidenced by less vigorous growth of plant life in the area and little slime growth on the rocks in the flow stream. The suspended solids may actually increase slightly in this area or more likely there may have been several poor samples taken on the July 13, 1994 sampling date.

With the exception of suspended solids, all other parameters are further reduced in concentration. Table 4 presents the tertiary treatment effluent concentrations. Removal efficiencies are based on the combined primary, secondary, and tertiary treatment.

TABLE 4: TERTIARY TREATMENT

Analyte	Average Concentration	Concentration Range	Average Removal
BOD_5 (mg/L)	<5	<5 to 6	>99%
TSS (mg/L)	29	<5 to 200	94%
Ammonia (mg/L)	0.49	<0.02 to 5.92	98%
Phosphorous (mg/L)	0.08	0.004 to 0.335	>99%
Fecal Coliform (CFU/100 ml)	1	0 to 9	>99%
Wastewater effluent entering Finger Bay (Columns K, L, M, N, O - Table 1)			

5.0 ISSUES FOR FURTHER STUDY

There is some discussion as to the biological activity of the frozen sewage mound in the winter. It is known that in the primary cell of a lagoon microbial activity, both anoxic and anaerobic, continues throughout the winter underneath the ice layer. Some microbial activity may also be continuing in the wetland's primary storage cell and sewage mound, beneath the ice cap, through the winter. Currently, the presence and significance of this activity is not known.

Secondly, the frozen sewage ice mound has often been assumed to melt rapidly in the spring, like the surrounding snow typically over two to three weeks. It appears that the ice mound however melts much more slowly, therefore not creating a flush of pollutants to the receiving waters. This slow melting allows the waste to be introduced gradually into the treatment system. These freeze-thaw dynamics have not been clearly documented.

There has also been some research into the cyclical freeze-thaw principles. The significance of layered freezing on sewage treatment has not been identified to date. There may be enhancement of sedimentation during the spring-thaw due to concentration of organics during freeze-up.

Presently, there is no consideration for treatment capacity beyond frost-free days. Some treatment activity, both biological and physical, is ongoing in the sewage mound, beneath the ice cap, over the winter months. Determination of the significance of these processes will require further study.

REGISTERED PROFESSIONAL ENGINEER
J. D. EWING
LICENSEE
N.W.T.

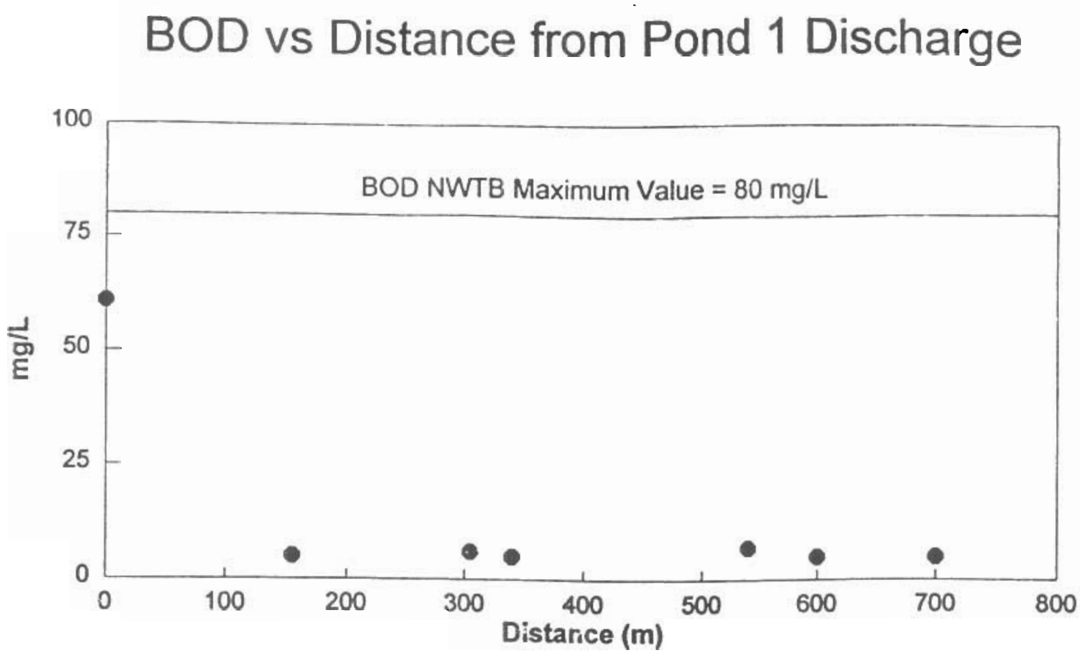
Respectfully submitted,

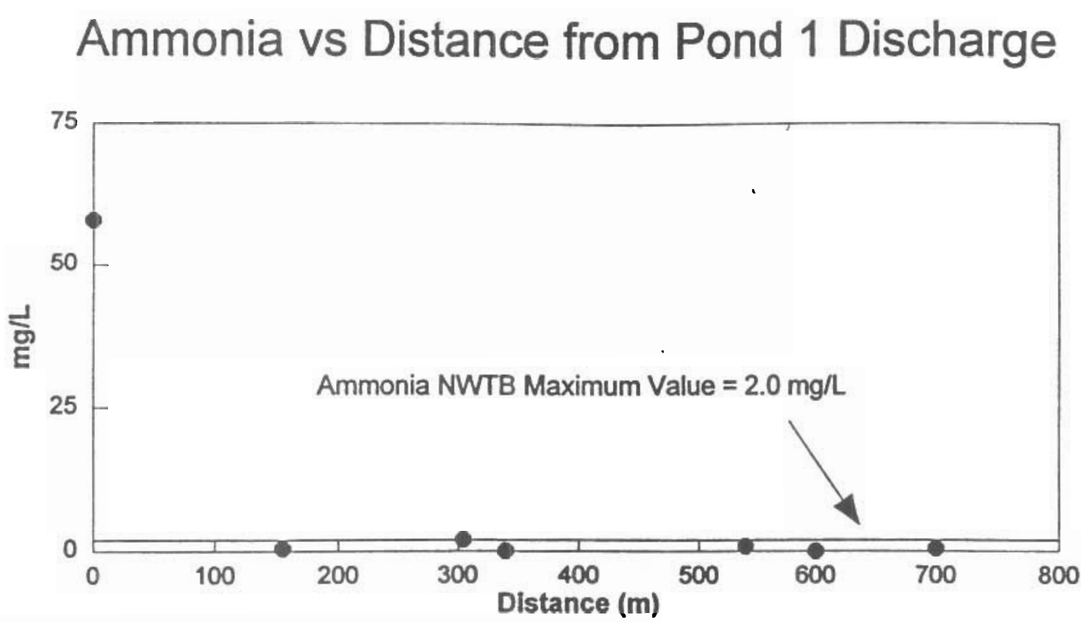
M. M. Dillon Limited

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 010
M. M. DILLON LIMITED

J. D. Ewing, P. Eng.
Senior Environmental Engineer

G. Strong, P. Eng.
Project Manager

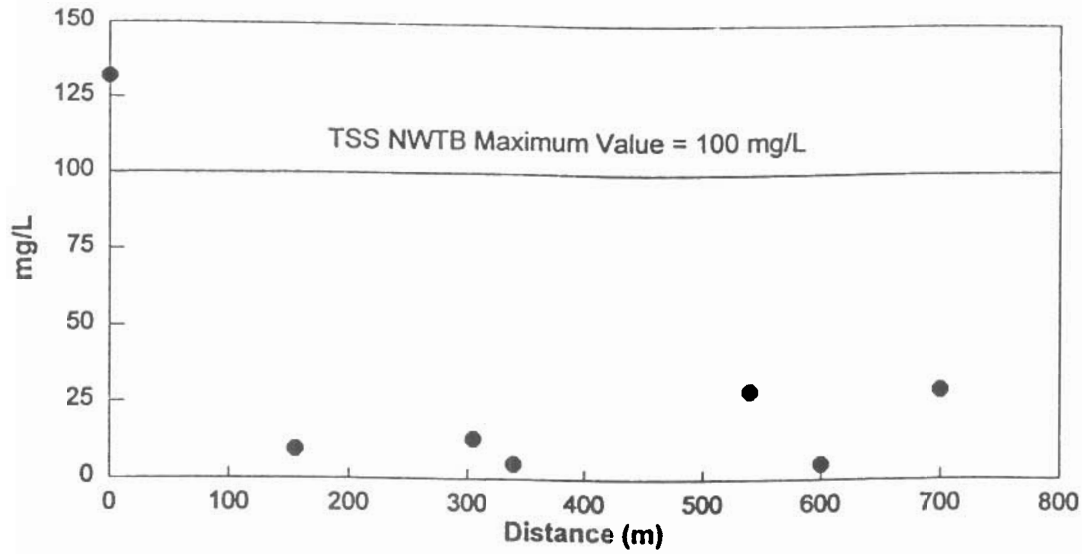




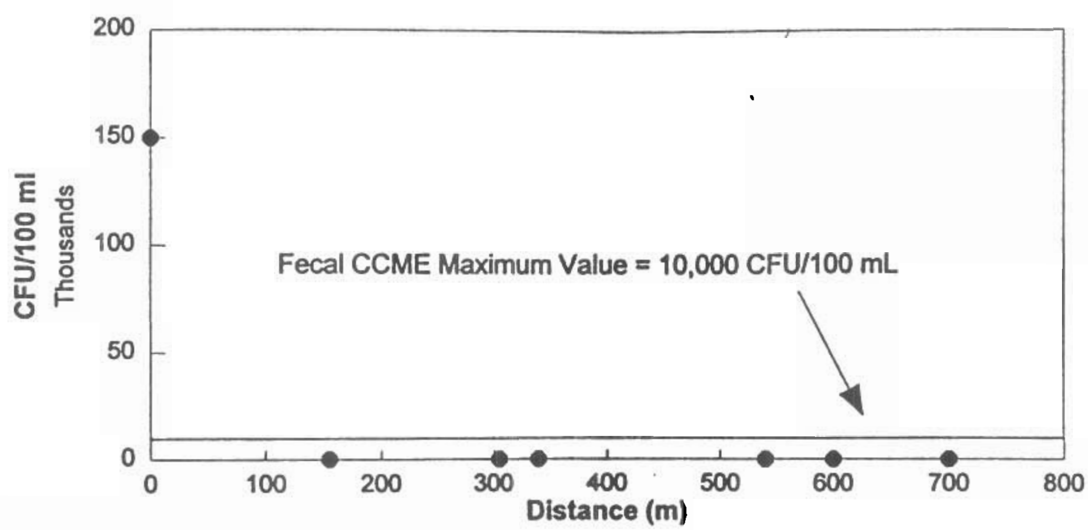
Note:

- 0 metres identified as discharge location from Pond 1.
- Data points calculated from six sample periods from June to August 1994.

TSS vs Distance from Pond 1 Discharge



Fecal Coliforms vs Distance from Pond 1 Discharge



Note:

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- Data points calculated from six sample periods from June to August 1994.

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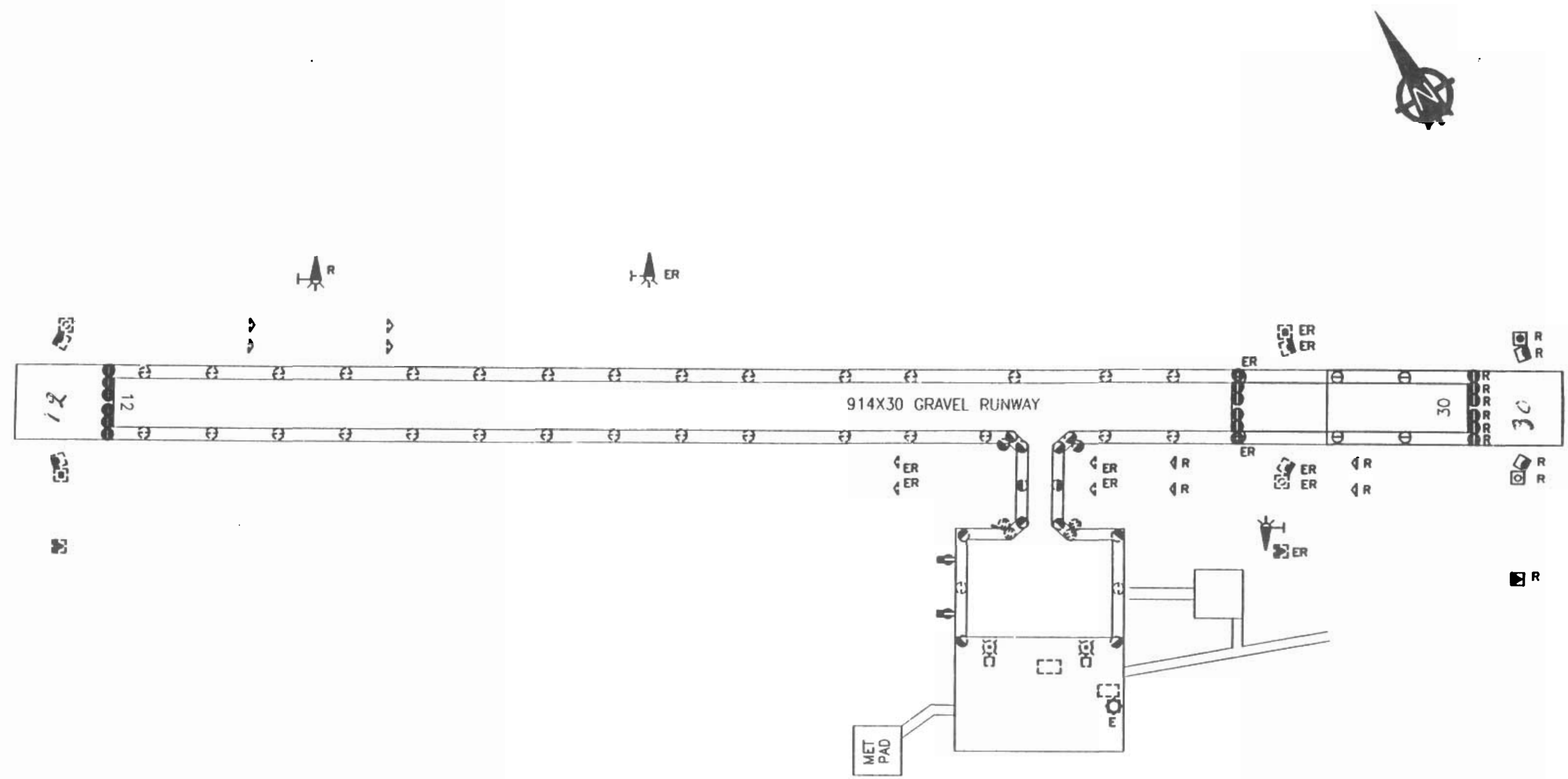

DATE	REVISIONS	APP

CHESTERFIELD INLET
AIRPORT LIGHTING

Reid Crowther
Reid Crowther & Partners Ltd.
☐ Consulting Engineers

SCALE N.T.S.
DATE JUNE 3, 1993
DES – DWN SMA
CKD RPM APP –
PROJ. No. 49330-01

DWG. No.
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